

A study on mosquitoes composition and malaria transmission in some communities in Doma Local Government Area of Nasarawa State, Nigeria

Osidoma, E. O.^{1*}, Pam, V. A.¹, Uzoigwe, N. R.¹, Ombugadu, A.¹, Omalu, I. C. J.², Maikenti, J. I.¹, Attah, A. S.¹, Ashigar, M. A.¹ and Dogo, S. K.¹

¹Department of Zoology, Faculty of Science, Federal University of Lafia, P. M. B. 146, Lafia, Nasarawa State, Nigeria.

²Department of Animal Biology (Parasitology and Tropical Diseases Research Unit), Federal University of Technology, Minna, Niger State, Nigeria.

*Corresponding author. Email: omakuosidoma@gmail.com, akwash24@gmail.com

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ABSTRACT: The paucity of information on malaria vectors in rural areas continues to pose a problem in the public health sector in Nigeria. Thus, the study on mosquitoes composition and malaria transmission in some communities in Doma Local Government Area (LGA) of Nasarawa State, Nigeria was carried out between April and July 2021. Indoor resting mosquitoes were collected using standard pyrethrum spray catch (PSC) from 0600 to 0900 hours. The mosquitoes collected were transferred into a well labelled petri-dish and transported to the laboratory for processing. A total of 1,317 mosquitoes were collected which spread across Iwashu 1,132 (85.9%) and Ruttu 185 (14.0%) communities. The results obtained indicate that the *Anopheles* mosquitoes had a higher abundance of 1,020 (77.4%) mosquitoes of which females constituted 886 (67.3%) of the population collected while the anopheline males accounted for 134 (10.2%). The abundance of mosquitoes in relation to groups, species and sex respectively varied significantly ($p < 0.05$). A zero (0.0%) sporozoite rate was recorded from the 654 female *Anopheles gambiae* s. l. dissected, although oocyst was seen in the alimentary canal of 78 (11.9%) mosquitoes which may be an indicator of possible potential transmission. The results obtained from this study call on all the inhabitants of the two selected communities as well as Doma LGA at large to always clear all potential mosquitoes breeding sites. Also, members of the communities should ensure proper protection against vector-human contact by sleeping under insecticide treated bed nets.

Keywords: Doma LGA, malaria, mosquitoes, pyrethrum spray catch, oocyst, sporozoite.

INTRODUCTION

Mosquitoes are primarily tropical insects, despite their global spread (Companion vector-borne disease, 2022) and proliferation in large numbers (WHO, 2010). Various species of mosquitoes have been incriminated to transmit some of the most harmful human and livestock diseases (Service, 1982). The parasitic disease collectively called malaria is caused by various species of *Plasmodium*, carried by female mosquitoes of the genus *Anopheles*. Lymphatic filariasis (the main cause of elephantiasis) can be spread by a wide variety of mosquito species. Viral

diseases, such as yellow fever, dengue fever, and chikungunya are transmitted mostly by *Aedes aegypti* (WHO, 2009). *Culex* and *Culiseta* are vectors of tularemia, as well as arbovirus infections such as the West Nile virus (Muslu *et al.*, 2011). The recent outbreak of mosquito-borne arbovirus which is of global health concern is the Zika virus transmitted by *Aedes* mosquitoes (Sejvar, 2018; Ward *et al.*, 2022).

Mosquitoes species such as *Anopheles gambiae*, *An. arabiensis*, and *An. funestus* are the main vectors of

malaria in Sub-Saharan Africa (Abeku *et al.*, 2015). There are over 2,500 species of mosquitoes but less than 50 are capable of transmitting malaria (Ahmed, 2007). In some cases, different forms are found in varying ecological regions, thus the need to identify the predominant malaria vectors in different ecological zones. Climatic factors have a direct impact on the entomological indices involved in malaria transmission as observed in the studies of Zyzak *et al.* (2002).

In 2019, Nigeria had the highest number of global malaria cases (27% of global malaria cases) and accounted for the highest number of deaths (23 % of global malaria deaths) (WHO, 2019) as well as an additional 8% rise in deaths as reported by WHO (2022). Oduola *et al.* (2012) noted that a large percentage of the population affected with malaria in the country lives below the poverty line in villages with poor healthcare facilities.

When a vector that spreads a disease is identified, then it is much simpler, cheaper and more cost effective to attack the vector rather than the pathogen (Wernsdorfer, 1986). Thus, this research investigated mosquitoes composition and malaria transmission in two rural communities of Doma Local Government Area (LGA), Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in Ruttu and Iwashi villages in Doma Local Government Area (LGA) of Nasarawa State, Nigeria. The LGA is boarded to the north by Lafia Local Government Area, to the east by Obi and Keana Local Government Areas, to the south by Benue State, and to the west by Nasarawa Local Government Area (Akwa *et al.*, 2007). Doma is located at 8°24'3.09"N and 8°21'29.28"E. It is situated in Nigeria's central belt. There are two distinct seasons in this region. The wet season runs from April to October, and the dry season runs from November to March. The average annual rainfall distribution in the area ranges from 100 to 1200 mm, while the minimum and maximum temperatures are 18.5°C and 35.0°C, respectively, and the topography of the area, particularly the relief of the study area, ranges between 49.5 and 793.5 m above sea level (Akwa *et al.*, 2007). Doma LGA has a land area of 2,714 km² and a population of 139,607 according to the 2006 census. Doma also had a total population of 90,719 in 1991, 139,607 in 2006, and a projected population of 187,600 in 2016 and 209,529 in 2020. Farming is the primary occupation of both men and women in the study region (Akwa *et al.*, 2007).

Mosquito collection and identification

Mosquitoes were collected from April to July 2021 in sixty (60) randomly selected houses from two villages, thirty

(30) houses from each village using a pyrethrum spray sheet in line with the World Health Organization standard of 1975 as adopted by AIRS Nigeria (2013) and Bayoh *et al.* (2014). During collection, five of the sixty selected houses were sprayed in various survey days between 6:00 am and 9:00 am. In each house, food items and drinking water were temporarily removed. White sheet were then sprayed on the beds and floor before spraying the house with pyrethroid aerosol insecticide (raid). After 10 minutes, the knocked down mosquitoes on the white clothes were picked using forceps and placed into labeled petri dishes containing moistened filter paper as described by WHO (2019) and transported to the Department of Zoology Laboratory, Federal University of Lafia in a cool box for identification and dissection. The collected adult mosquitoes were identified to species level using standard entomological keys by Gillies and De Meillon (1968), Gillies and Coetzee (1987) and Kent (2006).

Entomological transmission indices

Indoor resting density of mosquitoes

The indoor resting density (IRD) of female mosquitoes per structure per night was calculated using the formula by Williams and Pinto (2012).

$$\text{IRD} = \frac{\text{Total number of female vectors collected}}{\text{Total number of houses}}$$

Man-biting rate (MBR)

The man-biting rate (MBR) refers to the average number of bites per person per night by a vector species and depends on both the feeding habits of the vector and the night-time habits of the local people. The human biting rate per night is obtained by dividing the total number of female anopheles mosquitoes by the total number of human occupants who spent the night in the houses used for the collection using the standard formula by Williams and Pinto (2012) and Braack *et al.* (2015).

$$\text{MBR} = \frac{\text{No. of female mosquitoes collected (F)}}{\text{Total number of occupants (W) in the houses}}$$

Screening of malaria vectors for Sporozoite

A subset of the samples collected by PSC were dissected using a dissecting stereomicroscope and sterilized dissecting needles to detect the natural infection of *Plasmodium* parasites according to WHO (2020). Just before dissection, the mosquito was held by one wing and legs, proboscis and palps were detached one at a time after which the wings were then pulled off. The mosquito was soaked in distilled water with detergent for two

minutes, rinsed with distilled water then placed on a clean slide with the head pointing to the right-hand side. A drop of physiological saline was then added to keep the specimen fresh. The left dissecting needle was then placed gently on the thorax, just below the place where the salivary gland lies and the right needle was placed at the same time but on the opposite side. This was then gently pulled towards the right direction to bring out the salivary glands. The glands are then placed on another slide with a drop of normal saline and covered with a cover slip after which a gentle pressure was exerted on the cover slip to rupture the salivary gland. A drop of Giemsa stain was added and then left to air dry for 5 minutes as described by the World Health Organization (1975) and adopted by Manyi *et al.* (2014a). This was then washed with distilled water; air dried and then viewed under a microscope, using the x40 objective as described by WHO (2013).

Detection of oocyst in *Anopheles* mosquitoes

The abdomen of the female mosquitoes were dissected to check for oocysts. The abdomens were dissected at the 7th and 6th segments under a dissection microscope (Williams and Pinto, 2012). The ovaries were pulled out, and a little pressure was applied to burst the abdomen to bring out the Malpighian tubules and the stomach. This was then separated from other parts of the abdomen and transferred to a new slide. A drop of normal saline was added, then covered with a cover slip and examined under a compound microscope as described by Manyi *et al.* (2014a).

Sporozoite rate (S)

The number of female anopheline mosquitoes found with sporozoite after their salivary glands dissection was divided by the number of female anopheline dissected as described by Williams and Pinto (2012).

$$S = \frac{\text{Number of sporozoites positive mosquitoes}}{\text{Number of mosquitoes dissected}}$$

Statistical analysis

Data obtained was analyzed using R. Console software version 3.6. Simple descriptive statistics using percentage was used to determine the proportions. Pearson's Chi-square (χ^2) test was used to compare the proportion between anopheline mosquitoes across the two communities. T-test was used to compare the abundance of mosquitoes between the two selected communities. Pearson's Chi-square test was used to compare the entomological indices between the two communities. The level of significance was set at $p < 0.05$.

RESULTS

Composition and abundance of mosquitoes in the two communities

A total of 1,317 indoor resting adult mosquitoes collected belong to two mosquito groups (anopheline and culicine) which spread across six species as shown in Table 1. The anopheline population was higher 1,020 (77.4%) than the culicine group at 297 (22.6%). Thus, the abundance of mosquitoes between the two groups showed a very high significant difference ($\chi^2 = 396.91$, $df = 1$, $p < 0.001$). The predominant of mosquito species caught was *An. gambiae s. l.* 990 (75.2%) followed by *Cx. quinquefasciatus* 294 (22.3%) then *An. funestus* 28 (2.1%), *An. coustani* and *Mn. uniformis* had 2 (0.2%) each while *Ae. aegypti* was the least abundant 1 (0.1%) as shown in Table 1. Therefore, there was a very high significant difference ($\chi^2 = 3545.5$, $df = 5$, $p < 0.001$) in mosquito abundance between the six species recorded. A high significant difference ($\chi^2 = 835.54$, $df = 1$, $p < 0.001$) in mosquitoes' abundance in relation to sexes was observed in which female mosquitoes were more abundant 1,172 (89.0%) than males 145 (11.0%).

Comparison of female *Anopheles* species abundance in relation to the two locations surveyed

The number of indoor resting female *An.* species was more in Iwashi 759 (85.7%) than Ruttu 127 (14.3%). Therefore, the mean abundance of indoor resting female *Anopheles* mosquitoes in relation to locations showed a very high significant difference ($t = 4.1839$, $df = 30.653$, $p = 0.0002223$) (Figure 1).

Abdominal conditions of the female *Anopheles* mosquitoes caught

The majority of the female mosquitoes caught indoors were half-gravid 368 (41.5%) followed by fed individuals 367 (41.4%) then gravid ones 96 (10.8%) while unfed females were the least 55 (6.2%) as shown in Table 2.

Entomological transmission indices of malaria vectors

Indoor resting density (IRD)

The IRD of female *An.* mosquitoes in relation to Ruttu and Iwashi areas were 4.1 and 25.4 mosquitoes per room/night respectively (Table 3). In Ruttu community, *An. gambiae s. l.* had a higher IRD of 4.1 per room/night than *An. coustani* 0.07 per room/night. Also, IRD in Iwashi community favoured *An. gambiae s. l.* the most 25.4 mosquitoes per room per night while *An. funestus* had 0.9 mosquitoes per room per night as shown in Table 3.

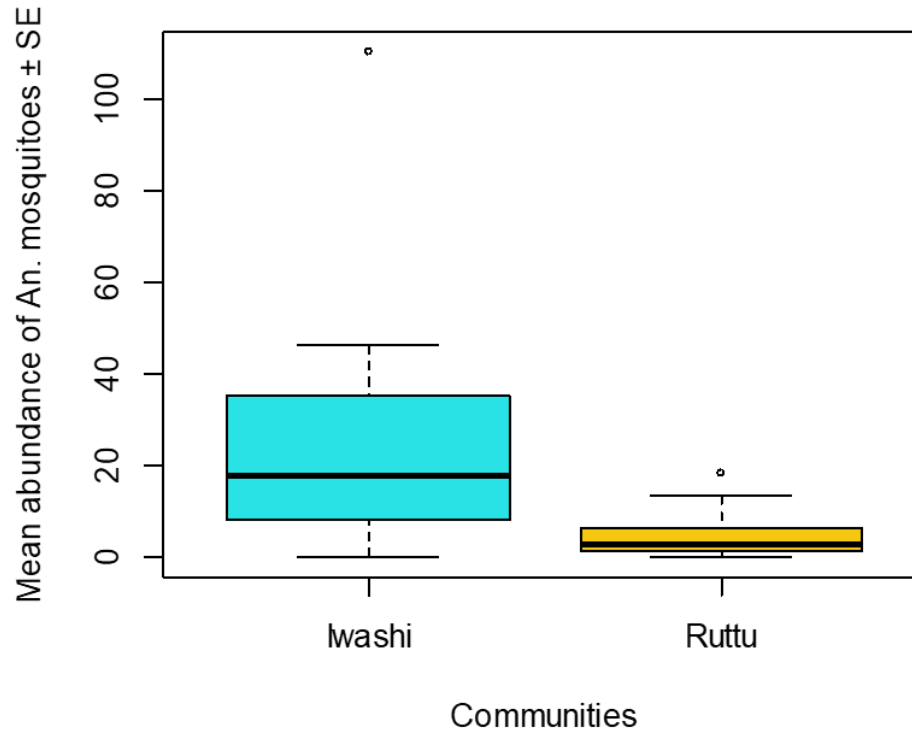


Figure 1. Mean abundance of indoor resting female *Anopheles* mosquitoes in two communities in Doma LGA, Nasarawa State, Nigeria.

Table 1. Checklist of mosquito species in Ruttu and Iwashi, Doma LGA, Nasarawa State, Nigeria between March and July, 2021.

Group	Species	Locations				Subtotal		Total (%)
		Ruttu		Iwashi		Male	Female	
		Male	Female	Male	Female			
Anopheline	<i>An. gambiae</i>	5	125	129	731	134	856	990 (75.2)
	<i>An. funestus</i>	0	0	0	28	0	28	28 (2.1)
	<i>An. coustani</i>	0	2	0	0	0	2	2 (0.2)
	Subtotal (%)	5 (3.8)	127 (96.2)	129 (14.5)	759 (85.5)	134 (13.1)	886 (86.9)	1020 (77.4)
Culicine	<i>Cx. quinquefasciatus</i>	5	50	6	233	11	283	294 (22.3)
	<i>Mn. uniformis</i>	0	2	0	0	0	2	2 (0.2)
	<i>Ae. aegypti</i>	0	1	0	0	0	1	1 (0.1)
	Subtotal (%)	5 (8.6)	53 (91.4)	6 (2.5)	233 (97.5)	11 (3.7)	286 (96.3)	297 (22.6)
	Total (%)	10 (5.4)	175 (94.6)	135 (11.9)	997 (88.1)	145 (11.0)	1172 (89.0)	1317

Table 2. Abdominal conditions of female *Anopheles* mosquitoes caught from Ruttu and Iwashi communities.

Abdominal condition	<i>Anopheles</i> species			Total (%)
	<i>An. gambiae</i>	<i>An. funestus</i>	<i>An. coustani</i>	
Unfed	51	2	2	55 (6.2)
Fed	356	11	0	367 (41.4)
Half gravid	355	13	0	368 (41.5)
Gravid	94	2	0	96 (10.8)
Total (%)	856 (96.6)	28 (3.2)	2 (0.23)	886

Table 3. Malaria vectors transmission indices in two locations in Doma LGA, Nasarawa State, Nigeria.

Species	No. of <i>An.</i> caught across locations		IRD/room		MBR/person	
	Ruttu	Iwashi	Rutu (n = 30 houses)	Iwashi (n = 30 houses)	Rutu (n = 84 persons)	Iwashi (n = 90 persons)
<i>An. gambiae</i>	125	731	4.17	24.37	1.49	8.20
<i>An. funestus</i>	0	28	0.00	0.93	0.00	0.30
<i>An. coustani</i>	2	0	0.07	0.00	0.02	0.00
Total	127	759	4.24	25.30	1.51	8.50

IRD: Indoor resting density; MBR: Man biting rate.

Table 4. Prevalence of *P. falciparum* developmental stages in *An. gambiae* s. l.

Location	No. examined	No. with oocyst (%)	No. with Sporozoite (%)
Ruttu	182	23 (12.6)	0 (0.0)
Iwashi	474	55 (11.6)	0 (0.0)
Total	654	78 (11.9)	0 (0.0)

Man biting rate (MBR)

The MBR of female *An.* mosquitoes across Ruttu and Iwashi communities were 1.42 and 8.5 mosquitoes per person/night (Table 3). An MBR of 1.4 and 0.2 mosquitoes per person/night for *An. gambiae* s. l. and *An. coustani* respectively was observed in Ruttu area while in Iwashi community, *An. gambiae* s. l. and *An. funestus* had an MBR of 8.2 and 0.3 mosquitoes per person per night respectively.

Sporozoite rate (S)

Of the 654 female *Anopheles gambiae* s. l. dissected, none (0.0%) had the *Plasmodium* infective stage (sporozoite), although oocyst was observed in the alimentary canal of 78 (11.9%) of them (Table 4).

DISCUSSION

The outcome of this study clearly shows that the two villages surveyed may highly be vulnerable to mosquito-borne infections based on the mosquito species recorded which are implicated as vectors of public health concern. Two mosquito groups were recorded from this study consisting of anopheline (77.4%) and culicine (22.3%). Iwashi community had a higher mosquitoes abundance than Ruttu.

Species wise, *An. gambiae* 990 (75.2%) was the most dominant followed by *Cx. quinquefasciatus* 294 (22.3%) while *Mansoni uniformis* and *An. constani* 2 (0.2%) each recorded the lowest abundance out of the six mosquito species recorded across the two communities studied. The

high prevalence of *An. gambiae* in this study could be attributed to the fact that the communities studied are situated in close proximity to freshwater bodies thereby providing favourable breeding grounds for these mosquitoes as compared to the culicines which prefer polluted breeding grounds. The high abundance of *Anopheles* species reported in this study conforms to the findings conducted in other parts of Nigeria (Dogara *et al.*, 2012; Manyi *et al.*, 2014b; Ezihe *et al.*, 2017) which recorded a higher prevalence of *Anopheles* species in their studies. Ombugadu (2020a) also reported a high abundance of *An. gambiae* in Lafia, Nasarawa State. Higher prevalence of *An. gambiae* was also reported in the study conducted by Ezeigwe *et al.* (2015) in six other states of Nigeria. However, a contrasting result was observed by Okorie *et al.* (2014) where 98% (1,756) of the total mosquitoes sampled in their study were *Culex* mosquitoes while only 1.9% (31) were *An. gambiae*. The result of their findings was attributed to the availability of polluted breeding grounds in residential areas of the town where the study was carried out. Previous results by Yoriyo *et al.* (2013) also observed a low proportion of *Anopheles* species (17.3%) as against *Culex* species (82.6%) collected in Gombe metropolis which had large area of polluted grounds that favours the breeding success of the culicines. Similarly, the study by Ombugadu *et al.* (2020b) reported a higher catch of *Culex* mosquitoes over *Anopheles* species.

The low prevalence of *An. funestus* observed in this research could possibly be due to the fact that *An. gambiae* are more anthropophilic, endophagic and endophilic as against *An. funestus* that are more zoophilic, exophagic and exophilic. This agrees with the result of Kilama (2010) who reported a lower abundance of *An. funestus* than *An. gambiae*. Also, Goupeyou-Youmsi *et al.*

(2020) recorded a low abundance of *An. funestus* in a study in two neighbouring villages of Madagascar. On the contrary, the result of Dazie *et al.* (2013) showed a high abundance of *An. funestus* 5,496 (53.6%) in Ghana which could be a result of variation in the ecology of their study area.

Findings from this study also recorded a very low abundance of *An. coustani* which concurs with Ombugadu *et al.* (2020b). But a sharp contrast was observed by Goupeyou-Youmsi *et al.* (2020) in a study in Madagascar who reported that *An. coustani* was the most abundant anopheline species due to rice farming in which grown-up rice plants over time shade the water of the rice fields which then makes farmland less favourable for the successful growth of the *An. gambiae* larvae thereby giving way to *An. coustani* larvae which prefer shaded breeding sites. This transition from *An. gambiae* s. l. to *An. coustani* in breeding sites by increasing vegetation cover was also demonstrated for borrow pits in Ethiopia (Kiszewski *et al.*, 2014).

The distinct variation observed in the abundance of indoor resting female *Anopheles* mosquitoes across locations could be attributed to the fact that Iwashi area has a more rural setting pattern based on the architectural designs of the houses made up of thatch roofs, unplastered walls with uncemented floors. On the other hand, Ruttu community had more modern houses with advanced roofing sheets, plastered walls, cemented floors, ceilings, doors and windows. It also has a well organize setting as compared to Iwashi. Although, Howell and Chadee (2007) and Ombugadu *et al.* (2022) found that indoor resting mosquitoes were significantly more abundant in homes made of cement type which provides a very smooth surface for endophilic mosquitoes to rest compared to mud and mud/block house.

The overall species specific indoor resting density (IRD) showed that *An. gambiae* had the highest IRD of 14.3 mosquitoes room/night which suggests its feeding and resting habits (endophagic and endophilic). The high IRD of 25 *Anopheles* mosquitoes per room/night in Iwashi area probably indicates a very high likelihood of contact activities between mosquito vectors and their human host. This finding is in conformity with the result of Onyido *et al.* (2008) and Ombugadu *et al.* (2020b) who reported a relatively high IRD of 8 and about 1 mosquito per room/night respectively.

The pooled man biting rate (MBR) of 5 mosquitoes per person/night in this investigation probably suggests a high occurrence of vector to man contact. The result of this study is similar to the works of Ombugadu *et al.* (2020a) who reported a man biting rate of 2.6 and 3.4 *An. gambiae* per man per hour in indoor and outdoor points respectively. Keana *et al.* (2016) also reported a high indoor MBR of 19.9 mosquitoes per person/night in south-central Ethiopia. Though Ombugadu *et al.* (2020b) recorded a low MBR of less than 0.5 malaria vectors/person/night in an Institution's students' hostels.

The absence of sporozoites in the dissected female

mosquitoes may be due to the fact that they had fed on uninfected individuals in the two surveyed communities. This result is similar to previous studies by Abdelwhab *et al.* (2021) in Central and Eastern Sudan who stated that fresh blood fed mosquitoes might have been freshly infected by early stages of *Plasmodium* parasites during their sexual life cycle such as mature gametes, zygotes, ookinetes, and oocysts (Elmahdi *et al.*, 2012). The appearance of sporozoites usually requires approximately two weeks from the time of ingestion of infected blood meal with malaria parasites by mosquito vectors (Kojin and Adelman, 2019). It may also be that sporozoites use circadian rhythm to travel through to salivary glands in order not to be affected by some enzymes within the wall of the intermediate host (mosquito) and thus remain in cyst until the vector is about going for blood meal before they may burst out of the oocyst (Stone *et al.*, 2013). Oocysts were observed in the dissection which might be proof that the parasite is still in the developmental stage.

Conclusion

The findings of this study have confirmed that there is a high prevalence of malaria vectors in the two selected villages which is an indication that the study area stands at risk of being endemic to *Plasmodium* infection. *An. gambiae* is the main malaria vector in the two villages surveyed. *An. coustani* was also reported in the study area although in a low abundance. The overall entomological transmission indices reveal both high indoor abundance of malaria vectors as well as vector-human contact. Also, a combination of control strategies such as the provision of long lasting insecticide nets, indoor residual spraying and elimination of mosquito breeding grounds is recommended to avoid human contact with the vectors. Further analysis is recommended to identify the *An. gambiae* complex vector to the sibling species level so as to guide future vector control programs.

CONFLICT OF INTEREST

The authors declare that they have not conflict of interest.

REFERENCES

- Abeku, T. A., Helinski, M. E., Kirby, M. J., Kefyalew, T., Awano, T., Batisso, E., Tesfaye, G., Ssekitooleko, J., Nicholas, S., Erdmanis, L., & Meek, S. R. (2015). Monitoring changes in malaria epidemiology and effectiveness of interventions in Ethiopia and Uganda: beyond Garki project baseline survey. *Malaria Journal*, 14, Article number 337.
- Abdelwhab, O. F., Elaagip, A., Albsheer, M. M., Ahmed, A., Paganotti, G. M., & Abdel Hamid, M. M. (2021). Molecular and morphological identification of suspected *Plasmodium vivax* vectors in Central and Eastern Sudan. *Malaria Journal*, 20, Article number 132.

- Ahmed, A. M. (2007). A dual effect for the black seed oil on the malaria vector *Anopheles gambiae*. Enhances immunity and reduce the concomitant reproductive cost. *Journal of Entomology*, 4(1), 1-19.
- AIRS Nigeria (2013). End of spray report. PMI/Africa IRS (AIRS) Project. Indoor Residual Spraying (IRS 2) Task Order Four. Submitted to: United States Agency for International Development/PMI p. 83.
- Akwa, V. L., Binbol, N. L., Samaila, K. I. & Markus, N. D. (2007). Geographical perspective on Nasarawa State. A publication of Geography Department, Nasarawa State University, Keffi, Nigeria.
- Bayoh, M. N., Walker, E. D., Kosgei, J., Ombok, M., Olang, G. B., Githeko, A. K., Killeen, G. F., Otieno, P., Desai, M., Lobo, N. F., & Gimnig, J. E. (2014). Persistently high estimates of late night, indoor exposure to malaria vectors despite high coverage of insecticide treated nets. *Parasites & vectors*, 7, Article number 380.
- Braack, L., Hunt, R., Koekemoer, L. L., Gericke, A., Munhenga, G., Haddow, A. D., Becker, P., Okia, M., Kimera, I., & Coetzee, M. (2015). Biting behaviour of African malaria vectors: 1. where do the main vector species bite on the human body? *Parasites & Vectors*, 8, Article number 76.
- Companion Vector-borne Diseases (2022). Mosquitoes are distributed widely throughout the ends of the continents. Retrieved from <https://cvbd.elanco.com/vectors/mosquitoes/general#:~:text=Mosquitoes%20are%20distributed%20widely%20throughout,the%20ends%20of%20the%20continents>
- Dogara, M., Nock, H., Agbede, R., Ndams, S., & Joseph, K. (2012). Entomological survey of mosquitoes responsible for the transmission of lymphatic filariasis in three endemic villages of Kano state, Nigeria. *The Internet Journal of World Health and Societal Politics*, 7(2), 1-6.
- Elmahdi, Z. A., Nugud, A. A., & Elhassan, I. M. (2012). Estimation of malaria transmission intensity in Sennar state, central Sudan. *Eastern Mediterranean Health Journal*, 18(9), 951-956.
- Ezeigwe, N., Inyama, P.U., Samdi, L.M., Akila, J.D., Awolola, T.S., Mwansat, G.S., Anyawu, G.I., Yayo, A.M., Ebere, N., Chukwuekezie, O., Seyuom, A., Inyang, U., Kafuko, J., Kolyada, L., Fornadel, C. & Norris, L. (2015). *Anopheles* Species Diversity, Behaviour, and Sporozoite Rates in Six States of Nigeria. *American Journal of Tropical Medicine and Hygiene*, 93(4), 425-425.
- Ezihe, E. K., Egbuche, C. M., Nwankwo, E. N., Ukonze, C., Anumba, J. U., Umenzekwe, C. C., & Ogudu, O. E. (2019). Malaria vector abundance and the incidence of malaria parasite amongst students living in nnamdi azikiwe university hostels. *International Journal of Tropical Disease and Health*, 37(4), 1-10.
- Gillies, M. T., & De Meillon, B. (1968). The anophelinae of Africa south of the Sahara (Ethiopian Zoogeographical Region). *Publications of the South African Institute for Medical Research*, 54, 1-343.
- Gillies, M. T., & Coetzee, M. (1987). A supplement to the anophelinae of Africa South of the Sahara (Afrotropical Region). Johannesburg: The South African Institute for Medical Research. 146pp.
- Goupeyou-Youmsi, J., Rakotondranaivo, T., Puchot, N., Peterson, I., Girod, R., Vigan-Womas, I., Paul, R., Ndiath, M. O., & Bourgouin, C. (2020). Differential contribution of *Anopheles coustani* and *Anopheles arabiensis* to the transmission of *Plasmodium falciparum* and *Plasmodium vivax* in two neighbouring villages of Madagascar. *Journal of Parasites & Vectors*, 13, Article number 430.
- Howell, P. I., & Chadee, D. D. (2007). The influence of house construction on the indoor abundance of mosquitoes. *Journal of Vector Ecology*, 32(1), 69-74.
- Kenea, O., Balkew, M., Tekie, H., Gebre-Michael, T., Deressa, W., Loha, E., Lindtjorn, B., & Overgaard, H. J. (2016). Human-biting activities of *Anopheles* species in south-central Ethiopia. *Parasites & vectors*, 9, Article number 527.
- Kent, R. J. (2006). The Mosquito of Macha, Zambia. PhD thesis in Johns Hopkins Malaria Research Institute, Department of Molecular Microbiology and Immunology, Johns Hopkins Bloomberg School of Public Health, Baltimore M.D. USA. 33pp.
- Kilama, W. L. (2010). Health research ethics in malaria vector trials in Africa. *Malaria Journal*, 9, Article number S3.
- Kiszewski, A. E., Teffera, Z., Wondafrash, M., Ravesi, M., & Pollack, R. J. (2014). Ecological succession and its impact on malaria vectors and their predators in borrow pits in western Ethiopia. *Journal of Vector Ecology*, 39(2), 414-423.
- Kojin, B. B., & Adelman, Z. N. (2019). The sporozoite's journey through the mosquito: a critical examination of host and parasite factors required for salivary gland invasion. *Frontiers in Ecology and Evolution*, 7, Article number 284.
- Manyi, M., Vajime, C., & Imandeh, G. N. (2014a). Sporozoite infection rate of female *Anopheline* mosquitoes in Makurdi, an endemic area for malaria in Central Nigeria. *International Journal of Entomological Research*, 2(2), 103-115.
- Manyi, M. M., Imandeh, G. N., & Azua, E. T. (2014b). Vectorial potential of *Anopheles* and *Culex* species in the transmission of bancroftian filariasis in the localities of Makurdi, North Central Nigeria. *Journal of Entomology and Zoology Studies*, 2(5), 171-177.
- Muslu, H., Kurt, O., & Özbilgin, A. (2011). Evaluation of mosquito species (Diptera: Culicidae) identified in Manisa province according to their breeding sites and seasonal differences. *Turkiye Parazitoloj Derg.* (in Turkish), 35(2), 100-104.
- Oduola, A. O., Otubanjo, O. A., Olojede, J. B., Oyewole, I. O., & Awolola, T. S. (2012). Malaria Transmission Risk Indices of three *Anopheles* species in selected Rural Communities in Oyo State. South-Western Nigeria. *International Journal of Tropical Medicine*, 7(1), 42-48.
- Okorie, P. N., Popoola, K. O. K., Awobifa, O. M., Ibrahim, K. T., & Ademowo, G. O. (2014). Species composition and temporal distribution of mosquito populations in Ibadan, Southwest Nigeria. *Journal of Entomology and Zoology Studies*, 2(4), 164-169.
- Ombugadu, A., Ekawu, R. A., Odey, S. A., Ajah, L., Adejoh, V. A., Micah, E. M., Samuel, M. D., Dogo, K. S., Ahmed, H. O., Ayim, J. O. & Angbalaga, G. A. (2020a). Feeding behaviour of mosquito species in Mararraba-Akunza, Lafia Local Government Area, Nasarawa State, Nigeria. *Biomedical Journal of Scientific & Technical Research*, 25(1), 18742-18752.
- Ombugadu, A., Maikenti, J. I., Maro, S. A., Vincent, S. O., Polycarp, I. A., Pam, V. A., Samuel, M.D., Adejoh, V. A., Attah, A. S., Ahmed, H. O., & Angbalaga, G. A. (2020b). Survey of mosquitoes in students hostels of Federal University of Lafia, Nasarawa State, Nigeria. *Biomedical Journal of Scientific & Technical Research*, 28(4), 21822-21830.
- Ombugadu, A., Jibril, A. B., Mwansat, G. S., Njila, H. L., Attah, A. S., Pam, V. A., Benson, R. F., Maikenti, J. I., Deme, G. G., Echor, B. O., & Nkup, C. D. (2022). Composition and Distribution of Mosquito Vectors in a Peri-Urban Community Surrounding an Institution of Learning in Lafia Metropolis,

- Nasarawa State, Central Nigeria. *Journal of Zoological Research*, 4(3), 20-31.
- Onyido, A. E., Deeza, N. P. L., Obiukwu, M., & Amadi, E. (2008). Ecology of man-biting mosquitoes in the development site of Nnamdi Azikiwe University Awka, Anambra State South Eastern Nigeria. *The Internet Journal of Health*, 9(2), 1-7.
- Sejvar, J. J. (2018). Zika virus and other emerging arboviral central nervous system infections. *Neuro Infectious Diseases*, 24(5), 1512-1534.
- Service, M. W. (1982). Ecological considerations in the biocontrol strategies against mosquitoes. In: Laird, M. (ed). *Biological control strategies of medical and veterinary pests*. Praeger New York. 175pp.
- Stone, W. J., Eldering, M., van Gemert, G. J., Lanke, K. H., Grignard, L., van de Vegte-Bolmer, M. G., Siebelink-Stoter, R., Graumans, W., Roeffen, W. F., Drakeley, C. J., & Bousema, T. (2013). The relevance and applicability of oocyst prevalence as a read-out for mosquito feeding assays. *Scientific Reports*, 3, Article number 3418.
- Ward, D., Gomes, A. R., Tetteh, K. K., Sepúlveda, N., Gomez, L. F., Campino, S., & Clark, T. G. (2022). Sero-epidemiological study of arbovirus infection following the 2015–2016 Zika virus outbreak in Cabo Verde. *Scientific Reports*, 12, Article number 11719.
- Wernsdorfer, W. H. (1986). Current approaches to malaria chemotherapy and prophylaxis. *Parasitology Today*, 2(9), 250-253.
- WHO (2022). World Malaria Report 2012. Geneva: World Health Organization.
- WHO (2020). World Malaria Report of global progress and challenges. Geneva.
- WHO (2019). World Malaria Report. 232pp.
- WHO (2010). Malaria in the Greater Mekong Subregion: Regional and country profiles: World Health Organization. In WHO Mekong Malaria Programme (013). Malaria entomology and vector control guide FOR Participants. 192p.
- WHO (2009). *Dengue Guidelines for Diagnosis, Treatment, Prevention and Control*. Geneva: World Health Organization.
- WHO (2013). Malaria entomology and vector control guide FOR Participants. 192pp.
- Williams, J., & Pinto, J. (2012). *Training manual on malaria entomology for entomology and vector control technicians (basic level)*. Integrated vector management of malaria and other infectious diseases task order 2
- Yoriyo, K. P., Alo, E. B., Napthali, R. S., Pukuma, S. M., Edward, S. A., & Muhammad, I. (2013). A quantitative study on the population of indoor resting density of mosquito species in four Local Government Areas of Gombe State, Nigeria. *Journal of Medical and Biological Sciences*, 3(1), 61-67.
- Zyzak, M., Loyless, T., Cope, S., Wooster, M., & Day, J. F. (2002). Seasonal abundance of *Culex nigripalpus* Theobald and *Culex salinarius* Coquillett in North Florida, USA. *Journal of Vector Ecology*, 27(1), 155-162.